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C-A OPERATIONS PROCEDURES MANUAL

9.1.11 Guideline for Radiological Controlled Area Classification and Radiation Access-Control System Application

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Collider-Accelerator Department Chairman Date

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9.1.11 Guideline for Radiological Controlled Area Classification and Radiation Access-Control System Application

1. Purpose

1.1 To define, for the Radiation Safety Committee (RSC), the classification of Radiological Controlled Areas and the Access Control Systems. These systems prohibit access or control the radiation dose received when the areas are accessed. Dose is controlled either by limiting radiation levels or preventing access when and where in the area levels are not limited appropriately. This procedure delineates the access, enclosure and minimum system requirements, for each Class of radiation area, and takes into account the potential levels of radiation during normal operations, and the potential increases in radiation levels with and without access.

> **Note:**
> C-A Class of area radiation levels are assigned by the radiation levels within the areas with or without access. Areas are 'named' by the radiation levels **when accessed; personal dose received is controlled via Radiation Work Permits.**

1.2. Definitions and Explanations

1.2.1 Access Allowed – Access Allowed States include *Procedural Access,* Restricted Access, or Controlled Access mode. Access control mode is under Main Control Room (MCR) operators who select the appropriate access mode.

1.2.2 Access Prohibited - In the access-prohibited state, areas may be fenced with locked gates, or if levels could exceed 50 rem/hr (Class I & II), the access control system disables slide bolts or electric strikes on all access doors. Here all access paths shall have a minimum of two sensors to detect an open door. If an interlock trips, two critical devices inhibit beam. Additionally, each access gate is equipped with a bolt-home micro-switch. The status of these gates is monitored from the MCR. For Class III the gates must be locked and have a sensor that monitors that the gate is closed or disables beam. For Class V & VI, gates shall be locked when access is prohibited.

1.2.3 Active - Active types of access control systems are either electronic devices OR written procedures.

1.2.4 Bypass - Temporary task-specific defeating of a single interlock function or group of functions. Also see Modification. Documentation of bypasses must be in accord with forms and procedures under the purview of the Access Controls Group, as indicated in OPM Chapter 4, or under the purview of the RSC using the written fault study procedures in C-A-OPM Chapter 9.

1.2.5 Controlled Access Mode - In Controlled Access, MCR Operators sweep the area clear of all personnel, then allow trained and authorized persons to enter and exit the area while keeping a log-in/log-out record. In this mode, an Operator is permitted to reset an area without a re-sweep.

1.2.6 Critical Device or Critical Circuits - The access control system inhibits beam via critical devices or critical circuits.

1.2.7 Crash Buttons - Emergency stop crash buttons, or cords, are in sight in the primary beam enclosures. They are visible under emergency lighting conditions. Crashes require local resetting. The status of crash buttons/cords are monitored in the MCR.

1.2.8 Dual (Redundant) - Two independent devices or interlock systems. Each device or interlock system is isolated from the other to perform a similar safety function, such that any single failure will not result in loss of protection.

1.2.9 “Enabled” indicates functional status and the presence or potential presence of beam. Under this condition there is the potential to create unwarranted radiation in nearby occupied areas. Access to areas that are contiguous to “enabled” areas must be evaluated, classified and appropriate systems put in place

1.2.10 Fail Safe - Predictable failures of the system leave the radiation access control system in a safe mode. The de-energized state of the relay is the fail-safe state.

1.2.11 Hardwired - Actual wiring between devices or mechanical switches, electromechanical relays, PLCs, and mechanical devices.

1.2.11.1 IF the design is sufficiently robust and appropriate engineering reviews are done and approved by the RSC, THEN specific active devices may be classified as hardwired.

1.2.11.2 Three active devices are currently classified as “hardwired” by the RSC: (1) interlocking chipmunk area-radiation monitors, (2) interlocking Nuclear Measurements Corporation (NMC) units, and (3) Rochester Instruments, Inc. "Fail-Safe Trip" units.

1.2.12 Interlock - An engineered system of devices that automatically prevent the use of accelerator-produced radiation that is hazardous to personnel.

1.2.13 Interlocked Beamlines - Areas or volumes into which entry is restricted by gates or barriers and interlocks to prevent personnel exposure to radiation.

1.2.14 Modification - Reconfiguring the interlock system for routine operations. Also see Bypass. Documentation of modifications must be in accord with forms and procedures under the purview of the Access Controls Group, as indicated in OPM Chapter 4. Modifications to procedures must follow requirements in OPM Chapter 1.

1.2.15 Primary Beam Enclosures - Enclosures containing un-collided beam capable of producing whole-body dose rates in excess of 50 rem/h.

1.2.16 Procedural Access – Access where requirements are enumerated in the RWP and/or associated work documents.

1.2.17 Reset - A state which allows beam to be introduced into a secured enclosure.

1.2.17.1 MCR Operators can turn the beam on after the enclosure sweep is complete and local reset and remote resets in the MCR are complete.

1.2.17.2 Upon MCR reset of primary beam enclosures the lights dim in the enclosure or an audible warning sounds, the Operators give an audible warning over the PA system, and a 30-second timer starts before beam can enter the enclosure.

1.2.18 Restricted Access Mode - In Restricted Access the doors are locked. Personnel require TLD’s at all times, and in radiation fields greater than 100 mrem/h, alarming dosimeters. Personnel require Radiation Worker Training and Collider Access Training prior to unescorted entry. Personnel meeting these requirements may enter the area on their own if they also meet the conditions of the applicable Radiation Work Permit (RWP) when Access is allowed.

1.2.19 Secondary Beam Enclosures - Enclosures containing the beams resulting from colliding a primary beam at fixed targets. The hazard from these beams may vary from being as high as from the primary beam itself, to levels not requiring access controls.

1.2.20 Upstream - An area or device closer to the source of beam.

2. Responsibilities

2.1. The Radiation Safety Committee is responsible for applying this guideline in the review of beam lines and all other pertinent C-A Radiological Areas.

2.2. The Committee may make exceptions to this guideline on a case-by-case basis, but may not exceed applicable BNL ES&H Standards (BNL Rad Con Manual), DOE Order 420.2 “Accelerator Safety”, or 10CFR835 “Occupational Radiation Protection”.

2.3. The cognizant Access Controls System Engineer is responsible for applying this guideline in designing and installing components, devices, and interlocks to meet the requirements defined by the RSC.

2.4 The Liaison Physicists and Engineers shall be trained in this procedure to properly prepare the design of an area for review.

3. Prerequisites

None

4. Precautions

4.1 Access to Primary Areas With Beam Enabled in Nearby Areas

Access to the switchyard and primary beam caves is limited as defined in the Primary Beam Accessibility Matrix, C-A-OPM-ATT 4.1.6.

5. Procedure

5.1 Design Principles

5.1.1 When Access is not allowed with beam on, the basic design principles of the access control system shall be:

5.1.1.1 Either the beam is disabled or the related access control area is secured.

5.1.1.2 The type of hardware or procedure required for each Radiological Class of area is given in C-A-OPM-ATT 9.1.11.a.

5.1.2 Redundancy is required if possible whole-body dose rate exceeds 50 rem/h at 1 foot from a source, or the in-beam dose rate, adjusted for size as in Section 5.5, exceeds 50 rem/h (Class I & II Areas).

5.1.3 IF a beam fails to be disabled as required by the state of its related access control area, THEN the upstream beam shall be disabled; that is, the system shall have reach-back.

5.2 Hardware and Posting Requirements

5.2.1 Class I & II Area hardware requirements are:

5.2.1.1 locked gates with dual independent interlock systems that react to the status of the gate position,

5.2.1.2 fail-safe radiation monitors, in some cases dual-interlocking fail-safe radiation monitors, directly in the beam path, or directly monitoring the beam intensity, to prevent beam excursions beyond operating limits imposed by the RSC,

Note:

This requirement for radiation monitors in the beam path is necessary if the area limits are at least one order of magnitude less than the capability of the accelerator. For example, one Nuclear Measurements Corporation (NMC) unit, or ion chamber, shall be allowed to protect against a factor of 10 in intensity excursion, and two independent NMC units, or ion chambers, for a factor of 100, whenever these excursions are possible. The RSC shall determine the locations of radiation monitors when used in this way.

5.2.1.3 status indicators at the area entrance and at the MCR,

5.2.1.4 warning lights or announcements to indicate status change, and

5.2.1.5 emergency stop devices such as crash buttons.

5.2.2 Class III Area hardware requirements are:

5.2.2.1 locked gates with interlock systems that react to the status of the gate position depending upon radiation level, see C-A-OPM-ATT 9.1.11.a,

5.2.2.2 in some cases fail-safe NMC radiation monitors, and in some cases redundant interlocking fail-safe NMC radiation monitors directly monitoring the beam intensity to prevent beam excursions beyond operating limits imposed by the RSC,

Example:

As an example, the NMC scintillation paddles may be used INSIDE a secondary beam enclosure to prevent beam intensity from exceeding the operating intensity by a factor of 2. Note that the INSIDE of an enclosure may be set up to encompass a broad range of excursions, for example 5 to 50 rem/h, thus, the NMC does not have to be very accurate when used in this way. They may be considered an AF Type security device and may be used to drop the excursion potential by one Class.

5.2.2.3 status indicators at the area entry and at the,

5.2.2.4 warning lights or announcements to indicate status change, and

5.2.2.5 emergency crash devices within Class III Areas where radiation levels may fault to greater than 50 rem/hr.

5.2.3 Class IV Area requirements are:

5.2.3.1 locked gates,

5.2.3.2 status given by procedure or fail-safe monitor,

5.2.3.3 in some cases fail-safe NMC radiation monitors, and in some cases redundant interlocking fail-safe NMC radiation monitors directly monitoring the beam intensity to prevent beam excursions beyond operating limits imposed by the RSC,

5.2.4 Class V & VI Area requirements are:

5.2.4.1 locked gates where specified,

5.2.4.2 status is given by procedure,

5.2.4.3 Chipmunk Radiation Monitors, where specified.

5.3 Classifying Areas

5.3.1 The RSC shall designate area classifications and the corresponding access control systems according to the guidelines given in C-A-OPM-ATT 9.1.11.a.

5.3.2 Users may be designated by the RSC to sweep and reset Class IV, V, & VI Areas.

5.3.3 The RCD, or an RSC designated individual, shall sweep and reset Class III and Class II Areas.

5.3.3.1 At least one member of the sweep team must be one of the: (1) RCD Technicians, (2) CAS Group, (3) C-A Supervisors, or (4) RSC members.

5.3.3.2 Designated personnel shall be trained using written procedures. Designated persons may also be Users, but they must be trained for this task.

5.3.3.3 The RSC shall define by special procedure, access to a reset Class II Area on a case-by-case basis. This special procedure shall define the access control needed to prevent a fault to Class I.

5.3.4 MCR operators shall sweep and reset, or supervise the sweep and reset, by CAS of Class I Areas.

5.3.4.1 Access to a reset Class I Area is prohibited.

5.3.5 The RSC shall use C-A-OPM-ATT 9.1.11.a to analyze individual components of a beam line in order to determine effects of radiation levels caused by component failure or mis-operation.

5.3.6 The RSC shall install multiple interlock systems where required; e.g., one to prevent access to an area during operations, a Class III Area for example, and another to prevent excursions to a Class II Area whenever the Class III Area must be occupied.

5.3.6.1 The RSC may use multiple access control systems to drop the excursion potential as follows:

5.3.6.1.1 A HFD Type access control system (see C-A-OPM-ATT 9.1.11.b) may be used to drop the maximum excursion potential to any lower level.

5.3.6.1.2. Under RSC approval, an AFD Type access control system may be used to drop the maximum excursion potential by ONE level.

Example:
An HFD Type interlock system (hardwire, fail-safe, dual) is used to prevent extraction of the primary proton beam down the B1 secondary beam-line. Another HFD Type A interlock system may limit the maximum secondary-beam fluence-rate into the B1 line to some fraction of the primary-beam intensity. For example, an HFD Type system is installed and it prevents a 6×10^{13} 30-GeV proton/pulse primary-beam from producing greater than 1×10^{8} pions/cm2-hr in the B1 secondary beam line. Thus, a potential Class I Area has been reduced to a potential Class III Area.

5.3.7 Equivalence

5.3.7.1 A Dual Active System is equivalent to a hardwire or mechanical system.

5.3.7.2 An Active Fail-Save Dual System is equivalent to a Hardwire Fail-Safe one.

5.3.7.3 Approved hardware devices can be used in place of hard-wired systems.

5.4 <u>Determination of In-Beam Absorbed Dose or Dose Equivalent Rate</u>

5.4.1 For a proton beam, use (see Reference 7.2):

$$\dot{D} = 7.15 x 10^{8} E^{0.175} Pf$$

$$\dot{H} = 1.37 x 10^{7} E^{0.342} Pf$$

where

$\dot{D}$ is the absorbed dose rate, rad in one hour

$\dot{H}$ is the dose equivalent rate, rem in one hour

E is the proton energy, GeV

P is the number of protons/cm^2 per pulse (particle fluence per pulse)

f is the number of pulses in one hour.

5.4.2 For a heavy ion beam, use:

$$\dot{D} = \left[\left(7.15 \text{ x } 10^{-8} E^{0.175} - 3.84 \text{ x } 10^{-8} E^{0.249}\right) Z^2 + 3.84 \text{ x } 10^{-8} E^{0.249} A\right] Pf$$

$$\dot{H} = \left[\left(7.15 \text{ x } 10^{-8} E^{0.175} - 3.84 \text{ x } 10^{-8} E^{0.249}\right) Z^2 + 1.07 \text{ x } 10^{-7} E^{0.405} A\right] Pf$$

where

$\dot{D}$, $\dot{H}$, and f as previously defined

E is the energy per nucleon, GeV

P is the number of ions/cm^2 per pulse (particle fluence per pulse)

A is the mass number

Z is the charge.

5.5 Adjustment for Small Beams Less Than 1000 cm^2 in

Note:

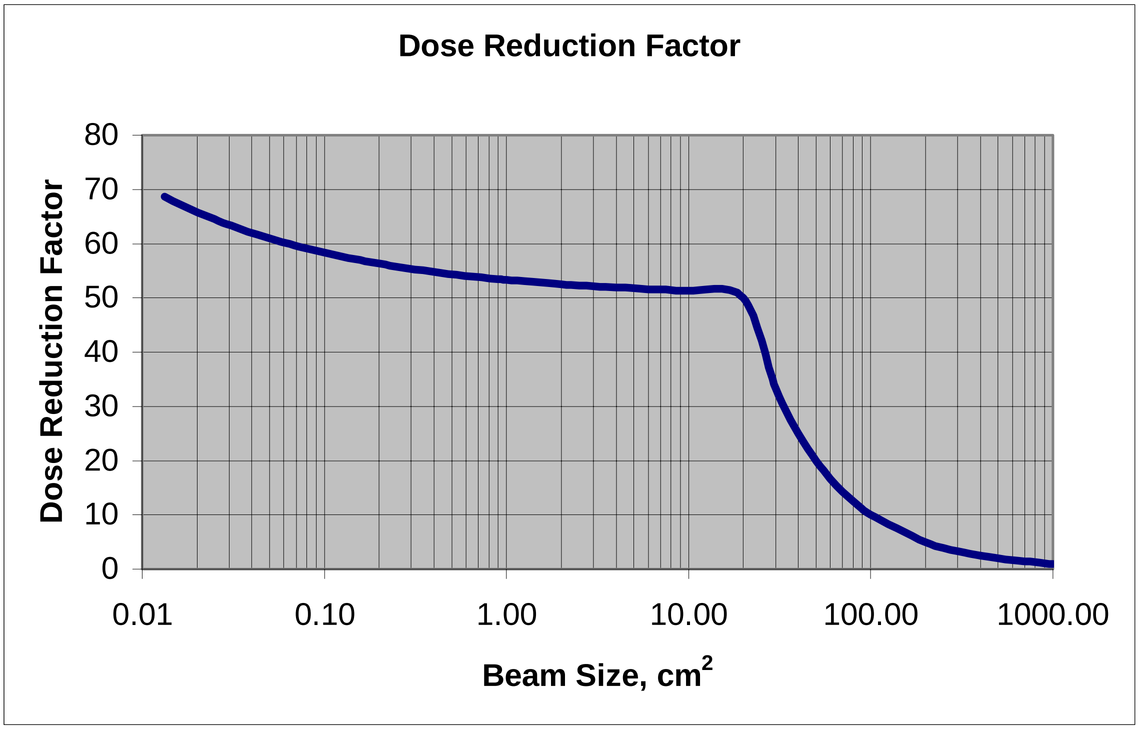
The Code of Federal Regulations, paragraph 835.502, (Reference 7.8) specifies a locked entry-way as the minimum access control for High Radiation and Very High Radiation Areas. The Federal rule also requires the RSC to implement unspecified additional measures to ensure individuals are not able to gain access to Very High Radiation Areas. Very High Radiation Areas are defined as areas where whole-body dose rates are in excess of 500 rad/h at 1 meter. The whole-body dose rate can be determined easily at 1 meter from a crashed beam. This makes comparison to the rule easy and direct. However, the rule is not easily related to in-beam exposures to small beams that may only cause non-lethal injuries. Hence, a simplified prescription is provided here in order to implement "additional measures".

The fluence rates for the small beams of ions in secondary areas generally do not cause lethal whole-body dose rates at 1 meter when crashed nearby. For example, the dose rate from a stopped Au beam of 10^5 ions/pulse is about 150 mrem/h at 1 meter; however, access to the beam-line area would require "additional measures" on the basis of in-beam dose rate from this same beam. At C-A, these "additional measures" are full enclosures, dual-redundant fail-safe gate interlocks, sweep and reset authorizations, and interlocking radiation monitors (see C-A-OPM-ATT 9.1.11.a).

As a minimum, all beam lines are either fully enclosed or fully surrounded by a locked 6-foot high fence or equivalent. Within the fenced areas, the RSC may allow gaps that are hand-sized, which is less than 4 inches. However, the gaps inside these fenced areas are also enclosed by netting and posted with signs indicating "Do Not Remove Without Permission". Thus, the minimum policy of the RSC is to meet the full enclosure rule in C-A-OPM-ATT 9.1.11.a, in addition to the locked entry-way rule of 10 CFR 835.

Warning:

The actual in-beam dose rate may be many times higher than the whole-body dose rate listed in C-A-OPM-ATT 9.1.11.a. The de-rating of dose rate for small beams accounts for the fact that only a small part of the body may be directly struck by the beam, leaving most of the body intact. However, significant deterministic effects may occur along the beam path as the beam penetrates the body. A de-rating factor inversely proportional to beam size (a^{-1}, where a is the beam size), has been used at C-A for many years for beam sizes between 1000 cm^2 and 20 cm^2, see Reference 7.6, Table VII. The RSC implies no radiobiological significance or health-physics significance to this prescription of a^{-1}. It's use is intended for the purpose of formally assigning additional measures for access control, measures that go beyond those specified in 10 CFR 835. The de-rating assumes, for bookkeeping purposes only, that a "reduced" dose rate from a small beam is an "equivalent hazard" to a whole-body dose rate of the same magnitude, even though actual deterministic effects are quite different. For smaller beam sizes the de-rating for "equivalent hazard" is assumed to follow a shallower slope. A slope of $a^{-0.4}$ is used for beams less than 20 cm^2 size, see Reference 7.3.



5.5.1 For beams less than 1000 cm^2 but larger than 20 cm^2 in size, determine the Class as follows:

Note:
See C-A-OPM-ATT 9.1.11.c for examples of beam fluence rate corresponding to C-A Class and dose rate guidelines for 20 cm^2 beam size.

5.5.1.1 Divide the actual in-beam absorbed dose or dose equivalent rate by: ratio of 1000 cm^2 to the actual beam size. For example, the maximum reducing factor for this range of beam size is 1000/20 = 50.

5.5.1.2 Compare this "reduced" dose to the values given for each Class in C-A-OPM-ATT 9.1.11.a.

5.5.2 For beams less than 20 cm^2 in size, determine the Class as follows:

5.5.2.1 Divide the actual in-beam absorbed dose or dose equivalent rate by: [(ratio of 20 cm^2 to the actual beam size)$^{0.4}$ plus 50]. For example, a 0.4 cm^2 beam size has a reducing factor of [20/0.4)$^{0.4}$ +50] = 55.

5.5.2.2 Compare this "reduced" dose to the values given for each Class in C-A-OPM-ATT 9.1.11.a.

5.6 IN ADDITION to in-beam dose, the RSC shall account for dose at penetration openings, at labyrinths, and at the outside surfaces of shielding; dose from residual radiation in shields, beam components or cooling water; and dose from muons.

5.6.1 The RSC shall delineate the access, enclosure and minimum access control requirements for each category of radiation area taking into account these additional radiation sources.

5.6.2 Dose equivalent rates for secondary particles produced from collided heavy-ion beams shall be calculated by assuming the nucleons of the heavy ion are independent.

5.6.3 Reference 7.4 provides an acceptable guide to assessing the dose from these additional sources; however, equivalent methods shall also be acceptable.

5.6.4 The barrier specifications for each Class are given in Reference 7.5.

6. Documentation

None

7. References

7.1 BNL memorandum from R. R. Rau, "Accelerator Department Radiation Safety Guidelines," September 10, 1974.

7.2 W. Armstrong and K. C. Chandler, “Calculation of the absorbed dose and dose equivalent from neutrons and protons in the energy range from 3.5 GeV to 1.0 TeV,” Health Physics, 24, 277-286 (1972).

7.3 Kjellberg, R. N., Davis, K. R., Lyons, S., Butler, W., and Adams, R. D., Bragg Peak Proton Beam Therapy for Arteriovenious Malformation of the Brain, Proceedings of the College of Neurological Surgeons, Williams and Wikers (Publisher), Baltimore, 1983.

7.4 H. Sullivan, A Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators, Nuclear Technology Publishing, Ashford, Kent TN23 1JW, England, 1992.

7.5 C-A-OPM 9.1.10, "Specifications for C-A Radiation Barriers."

7.6 R. McCall, W. R. Casey, L. Coulsen, J. McCaslin, A. Miller, K. Crook, T.

Simmons, Health Physics Manual of Good Practice for Accelerator Facilities, SLAC-327, April 1988.

7.7 BNL RadCon Manual

7.8 Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection.

8. Attachments

8.1. C-A-OPM-ATT 9.1.11.a, "General Guideline for C-A Radiation Access-Control System Classification and Application".

8.2. C-A-OPM-ATT 9.1.11.b, "Types of Access-Control Systems and Their Characteristics".

8.3 C-A-OPM-ATT 9.1.11.c, "Examples of Beam Flux Corresponding to AGS Class and Dose Rate Guidelines for Beams 20 cm^2 In Size".